UTILITY PATENT APPLICATION TRANSMITTAL (Only for new nonprovisional applications under 37 CFR 1.53(b))	Attorney Docket No.	**000489**	Total Pages	
	First Named Inventor or Application Identifier			
Check Box, if applicable [ ] Duplicate	**Hideaki YOSHIDA; Hatsuo SHIMIZU**			
	Express Mail Label No.			

APPLICATION ELEMENTS FOR:	ADDRESS TO: Assistant Commissioner for Patents
COLOR IMAGE PICKUP DEVICE AND COLOR IMAGE PICKUP APPARATUS	BOX PATENT APPLICATIONS Washington, D.C. 20231

1. [XX] Fee Transmittal Form (Incorporated within this form)
(Submit an original and a duplicate for fee processing)

2. [XX] Specification   Total Pages [58]

3. [XX] Drawing(s) (35 USC 113)   Total Sheets [5]

4. [XX] Oath or Declaration   Total Pages [5]

  a. [XX] Newly executed (original or copy)

  b. [ ] Copy from prior application (37 CFR 1.63(d))
    (for continuation/divisional with Box 17 completed).

    i. [ ] Deletion of Inventor(s)
      Signed statement attached deleting inventor(s) named in prior application,
      see 37 CFR 1.63(d)(2) and 1.33(b).

5. [ ] Incorporation by reference (useable if box 4b is checked)
The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under box 4b, is considered as being part of the disclosure of the accompanying application and is incorporated by reference therein.

6. [ ] Microfiche Computer Program (Appendix)

7. [ ] Nucleotide and/or Amino Acid Sequence Submission (if applicable, all necessary)

  a. [ ] Computer Readable Copy
  b. [ ] Paper Copy (identical to computer copy)
  c. [ ] Statement Verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. [XX] Assignment Papers (cover sheet and document(s))

9. [ ] 37 CFR 3.73(b) Statement (when there is an assignee)   [XX] Power of Attorney

10. [ ] English translation Document (if applicable)

11. [ ] Information Disclosure Statement [ ] Copies of IDS Citations

12. [ ] Preliminary Amendment

13. [XX] Return Receipt Postcard (MPEP 503)

14. [ ] Small Entity Statement(s) [ ] Statement filed in prior application Status still proper and desired.

15. [XX] Claim for Convention Priority [4] Certified copy of Priority Document(s)

 a. Priority of __Japanese__ application no's. __11-107371; 11-107372; 11-107440 and 11-125494__ filed on __April 15, 1999;__ __April 15, 1999; April 15, 1999 and May 6, 1999__ is claimed under 35 USC 119.
  (For Continuing Applications, if applicable).

16. [ ] Other _____

17. If a CONTINUING APPLICATION, check appropriate box and supply the requisite information:

 [ ] Continuation [ ] Division [ ] Continuation-in-part (CIP) of prior application no. _____/_____

FEE TRANSMITTAL The filing fee is calculated below	Number Filed	Number Extra	Rate	Basic Fee $690.00
Total Claims	32 - 20	12	x $18.00	216.00
Independent Claims	8 - 3	5	x $78.00	390.00
Multiple Dependent Claims			$260.00	
			Basic Filing Fee	1,296.00
Reduction by 1/2 for small entity				
Fee for recording enclosed Assignment			$40.00	40.00
TOTAL				1,336.00

UTILITY PATENT APPLICATION TRANSMITTAL (Only for new nonprovisional applications under 37 CFR 1.53(b))	Attorney Docket No.	000489
	First Named Inventor or Application Identifier	
	Hideaki YOSHIDA; Hatsuo SHIMIZU	
	PAGE 3 OF 3	

[XX] A check in the amount of __$1,336.00__ is enclosed to cover the filing fee of __$1,296.00__ and the assignment recordation fee of __$40.00__.

[ ] Please charge our Deposit Account No. **01-2340** in the total amount of _____ to cover the filing fee and the _____ assignment recordation fee. A duplicate of this sheet is attached.

[XX] The Commissioner is hereby authorized to charge payment for any additional filing fees required under 37 CFR 1.16 or credit any overpayment to Deposit Account No. **01-2340**. A duplicate of this sheet is attached.

18. CORRESPONDENCE ADDRESS

<div align="center">

ARMSTRONG, WESTERMAN, HATTORI
McLELAND & NAUGHTON
1725 K Street, N.W. Suite 1000
Washington, D.C. 20006
Telephone: (202) 659-2930
Facsimile: (202) 887-0357

</div>

SUBMITTED BY		
Typed or Printed Name:	William F. Westerman	Reg. No. **29,988**
Signature		Date: **April 14, 2000**

WFW/klh

SPECIFICATION

Title of the Invention

COLOR IMAGE PICKUP DEVICE AND COLOR IMAGE PICKUP APPARATUS

This application claims benefits of Japanese Patent Applications No. Hei 11-107371, No. Hei 11-107372 and No. Hei 11-107440 filed in Japan on April 15, 1999, and No. Hei 11-125494 filed in Japan May 6, 1999, the contents of which are incorporated by these references.

Background of the Invention

The present invention relates to a color image pickup device capable of preventing color moire from occurring and relates to color image pickup apparatus using such color image pickup device.

The image pickup devices typically represented by image pickup tube and solid-state image pickup device are widely used in image pickup apparatus. Especially, those color image pickup devices used in single-tube or single-sensor color image pickup apparatus, because of their capability of constructing a color image pickup apparatus by a single image pickup device, greatly facilitates downsizing/power saving of the color image pickup apparatus, since they are characterized in that: a color separation

prism is not required and a reduction in size of lens is possible; various adjustments in a multiple-sensor system such as registration are not required; and dissipation power is smaller. In particular, a majority of image pickup apparatus are manufactured as a single-sensor color camera using color CCD image pickup device which is among the solid-state image pickup devices.

In order to obtain color information by a single light-receiving surface, the above described color image pickup devices, without exception, are to perform color modulation (color coding) within the light-receiving surface by using a color filter such as the so-called stripe filter or mosaic filter. For example, a different spectral sensitivity is imparted to each of the pixels by putting filters of the three colors of RGB on the respective photoelectric conversion elements (pixels) in a predetermined, regular order of arrangement. The image signals obtained from an imaging of object thus contain a point-by-point, sequential color information according to such filter array, and the color information can be read out by extracting separated signals by means of separation by each signal corresponding to each filter in accordance with the above described array. Since all pieces of information of RGB are necessary to obtain a luminance signal (Y signal), at least 3 pixels (one each for RGB) are necessary

2

to obtain the luminance information of one pixel. Hence an image can be picked up in colors by using a single image pickup device even though luminance resolution is somewhat sacrificed.

The various types of color coding patterns having been proposed/used as the above described filter array of color filters include: such filter arrays of three primary colors as RGB stripe, Bayer-type RGB mosaic (various types) ; and such complementary-color filter arrays as YeMgCy stripe, YeMgCyW 4-color mosaic, YeMgCyG 4-color mosaic.

The present invention aims at pointing out and hence providing a remedy for an essential problem which is inherent to the above described color image pickup device irrespective of its electrical construction (whether it comprises an image pickup tube or a solid-state image pickup device, whether it is of the CCD type or other types, etc.) and/or the kind of color coding (whether it uses primary colors or complementary colors, whether it uses three colors or four colors, etc.). For this reason, the following description will be explained by way of an example only, unless otherwise specified.

Of the above described known color coding arrays, an example of RGB Bayer array will now be described by way of Figs.1A and 1B. The RGB Bayer array contains a basic array consisting of 2×2 or 4 pixels as shown in Fig.1A. Such

3

basic arrays are sequentially arranged so as to fill a plane as shown in Fig.1B. This is characterized in that an allocating ratio of pixels respectively for RGB of 1:2:1 is used so that the luminance resolution be enhanced by increasing the density of G which has a greater contribution to luminance signal. Further, since the same order of arrangement is used along the two directions of vertical and horizontal, it is possible, unlike a stripe type filter, to obtain an isotropic resolution. It should be noted that Fig.1B shows an example of arbitrarily selected, 8×8=64 pixels.

Since, however, the above RGB Bayer array uses a regular order of arrangement in the manner as described above, there has been a great disadvantage that it involves the so-called color moire, a spurious resolution due to the spatial sampling according to such arrangement. In particular, suppose that a black-and-white object originally having no hue contains a cyclic object where luminance change (black-and-white pattern) occurs at the same cycle as the cycle in the above Bayer array. For example, when a row consisting of RG is noticed and considered as one horizontal line, suppose that the object is white at R filters and black at G filters. Since signals to be outputted are equivalent to the signals obtained from a red object without having luminance change, this results

in an outputting of hue which originally does not exist.
Such false color signal resulting from a pattern consisting
of a stripe-like repetition, i.e., color moire occurs in a
low-frequency region due to the so-called frequency folding
(aliasing) and hence cannot be removed even by an
electrical filtering or the like including a color band
suppression to be performed at a later stage.

For this reason, the conventional single-sensor
color image pickup apparatus necessitates an optical low-
pass filter such as of crystal in its optical system in
order to secure image quality. This greatly impedes
downsizing and/or cost saving. In addition, a lowered image
quality due to yet remaining color moire has not been able
to be avoided.

Summary of the Invention

To essentially solve the problem involved in the
above described cyclic color coding array of color image
pickup device in the conventional color image pickup
apparatus, it is an object of the present invention to
provide a color image pickup device in which it is possible
to keep color moire from occurring even of an object having
a cyclic luminance change without using an optical low-pass
filter.

In accordance with a first aspect of the invention,

5

a color image pickup device includes: a pixel group placed in an array of a plurality of pixels of photoelectric conversion elements; and a color coding array corresponding to the pixel group, arranged in a randomized array.

It is possible with a color image pickup device of such construction to pick up an object image according to the random color coding array having no regularity and hence to pick up a color image free from color moire even of an object having a cyclic luminance change without using an optical low-pass filter. The above object is thereby accomplished.

It is another object of the present invention to provide a color image pickup apparatus capable of securely performing color separation based on color coding information of a color image pickup device which keeps color moire from occurring.

In a second aspect of the invention, a color image pickup apparatus includes: a color image pickup device having a pixel group placed in an array of a plurality of pixels of photoelectric conversion elements and a color coding array corresponding to the pixel group, arranged in a randomized array; and color separation means for performing color separation processing of output signals of the color image pickup device based on the random color coding array of the color image pickup device.

6

With a color image pickup apparatus of such construction, an imaging free from color moire is possible without using an optical low-pass filter and at the same time color separation can be performed as based on the color coding array information of the color image pickup device. The above object is thereby accomplished.

The color image pickup apparatus according to the above second aspect preferably includes storage means for storing array data concerning the random color coding array of the color image pickup device, for performing color separation processing at the color separation means. By thus providing the storage means for storing the color coding array data of the color image pickup device, color separation based on the random color coding array information can be performed easily and securely.

Further, the storage means of the color image pickup apparatus according to the second aspect is preferably constituted by mask ROM. By thus using mask ROM as the means for storing color coding array data, the storage means and hence the color image pickup apparatus can be manufactured in large quantities at relatively low costs.

Further, the storage means of the color image pickup apparatus according to the above second aspect is preferably constituted by EEPROM. By thus using EEPROM as the means for storing color coding array data, it is

possible to readily correspond to color separation processing of a color image pickup device having a different color coding array.

It is a further object of the present invention to provide a color image pickup device capable of picking up a color image where image quality performance such as a predetermined resolution is secured free from color moire without using an optical low-pass filter.

In a third aspect of the invention, a color image pickup device includes: a pixel group placed in an array of a plurality of pixels of photoelectric conversion elements; and a color coding array corresponding to the pixel group, arrayed in a randomized array satisfying predetermined array restricting conditions.

It is possible with a color image pickup device of such construction to pick up an object image according to a random color coding array having no regularity. At the same time, since the random array satisfies predetermined array restricting conditions, a color imaging is possible with securing a predetermined image quality performance (such as resolution) free from color moire. The above object is thereby accomplished.

Further, in a fourth aspect of the invention, a color image pickup device includes: a pixel group placed in an array of a plurality of pixels of photoelectric

8

conversion elements; and a color coding array corresponding to the pixel group, arrayed in a randomized array satisfying predetermined color distributing conditions.

It is possible with a color image pickup device of such construction to pick up an object image according to a random color coding array having no regularity. At the same time, since the random array satisfies predetermined color distributing conditions, a color imaging is possible with securing a predetermined image quality performance (such as resolution) free from color moire. The above object is thus accomplished also by the color image pickup device according to the fourth aspect.

Here, the above array restricting conditions in the color image pickup device according to the third aspect are preferably minimum density conditions concerning colors. By imparting such array restricting conditions, a resolution equal to or better than a predetermined value can be maintained over the entire image pickup region.

It is a further object of the present invention to provide a color image pickup apparatus capable of securely performing color separation as based on color coding array information of a color image pickup device which keeps color moire from occurring and has a predetermined image quality performance.

In a fifth aspect of the invention, a color image

pickup apparatus includes: a color image pickup device having a pixel group placed in an array of a plurality of pixels of photoelectric conversion elements and a color coding array corresponding to the pixel group, arrayed in a randomized array satisfying predetermined array restricting conditions; and color separation means for performing color separation processing of output signals of the color image pickup device in accordance with the random color coding array of the color image pickup device.

With a color image pickup apparatus of such construction, it is possible without using an optical low-pass filter to pick up an image with keeping color moire from occurring and with securing a predetermined image quality performance, and at the same time color separation can be securely performed as based on the color coding array information of the color image pickup device. The above object is thereby accomplished.

In a sixth aspect of the invention, a color image pickup apparatus includes: a color image pickup device having a pixel group placed in an array of a plurality of pixels of photoelectric conversion elements and a color coding array corresponding to the pixel group, arrayed in a randomized array satisfying predetermined color distributing conditions; and color separation means for performing color separation processing of output signals of

the color image pickup device in accordance with the random color coding array of the color image pickup device.

With a color image pickup apparatus of such construction, it is possible without using an optical low-pass filter to pick up an image with keeping color moire from occurring and with securing a predetermined image quality performance, and at the same time color separation can be securely performed as based on the color coding array information of the color image pickup device. The above object is thus accomplished also by the color image pickup apparatus according to the sixth aspect.

The color image pickup apparatus according to the above fifth or sixth aspect preferably includes storage means for storing array data concerning the random color coding array of the color image pickup device, for performing color separation processing at the color separation means. By thus providing the storage means for storing the color coding array data of the color image pickup device, color separation based on the random color coding array information can be performed easily and securely.

Further, the storage means of the color image pickup apparatus according to the above fifth or sixth aspect is preferably constituted by mask ROM. By thus using mask ROM as the means for storing color coding array data, the

1 1

storage means and hence the color image pickup apparatus can be manufactured in large quantities at relatively low costs.

Furthermore, the storage means of the color image pickup apparatus according to the above fifth or sixth aspect is preferably constituted by EEPROM. By thus using EEPROM as the means for storing color coding array data, it is possible to readily correspond to color separation processing of a color image pickup device having a different color coding array.

It is a further object of the invention to provide a color image pickup apparatus having a relatively small size and manufactured at low costs in which a high quality color imaging is possible with keeping color moire from occurring even of an object having a cyclic luminance change and at the same time a favorable image with compensating fault pixels can be obtained even when pixel defects occur in the image pickup device.

In a seventh aspect of the invention, a color image pickup apparatus includes: a color image pickup device having a pixel group placed in an array of a plurality of pixels of photoelectric conversion elements and a color coding array corresponding to the pixel group, arranged in a randomized array; storage means for storing array data concerning the color coding array and pixel defect data of

the color image pickup device; and color separation means for generating color signals in accordance with the color coding array data stored in the storage means, said color separation means performing a predetermined pixel defect correction in the color signal generating process based on the pixel defect data stored in the storage means.

With the color image pickup apparatus having such construction, since an object image is picked up by using a color image pickup device having a randomized color coding array without cyclicity and color signals are generated based on the color coding array data, a high quality color imaging free from color moire is possible even of an object having a cyclic luminance change. Further, since pixel defect correction is performed at the same time in the color signal generating process by the color separation means based on the pixel defect data of the color image pickup device, a favorable image with compensating fault pixels can be obtained even when pixel defects exist in the color image pickup device. The above object is thereby accomplished.

Here, the predetermined pixel defect correction processing by the color separation means in the color image pickup apparatus according to the seventh aspect is preferably performed such that an output signal of the pixel nearest to the fault pixel among the pixels of the same

color as the color of signal to be supplemented for the
fault pixel is used to supplement an output signal of the
fault pixel. By such construction, use of the color image
pickup device especially which satisfying a predetermined
color coding array restricting conditions makes it in effect
possible to keep a degradation in resolution from occurring
even if an isolated pixel defect exists.

Further, the storage means of the color image pickup
apparatus according to the seventh aspect is preferably
constituted by EEPROM. By such construction, it becomes
possible to readily correspond to color separation or pixel
defect correction processing of a color image pickup device
which is different in color coding array or in the manner of
pixel defects.

Brief Description of the Drawings

Fig.1A and 1B show an example of a basic array and
the entire array of color filter arranged in a conventional
RGB Bayer array.

Fig.2 is a block diagram showing a first embodiment
of color image pickup apparatus using the color image pickup
device according to the invention.

Fig.3 shows an example of color filter of a random
color coding array of CCD image pickup device in the
embodiment shown in Fig.2.

Fig.4 shows an example of color filter of random color coding array satisfying predetermined array restricting conditions for CCD image pickup device in a second embodiment of the invention.

Fig.5 shows an example of color filter of random color coding array satisfying predetermined color distributing conditions for CCD image pickup device in a third embodiment of the invention.

Fig.6 shows a modification of color filter of random color coding array satisfying the color distributing conditions shown in Fig.5.

Fig.7 shows an example of color filter of random color coding array satisfying predetermined color coding array conditions for CCD image pickup device in a fourth embodiment of the invention.

Description of the Preferred Embodiment

Some embodiments of the invention will now be described. Fig.2 is a block diagram showing a digital camera according to a first embodiment of the color image pickup apparatus using a color image pickup device of the present invention. Fig.2 includes: a lens system 1; a lens drive mechanism 2; an exposure control mechanism 3; a CCD image pickup device 4 having color filters arranged in a randomized array; a CCD driver 5; a preprocessing circuit 6

1 5

including an analog-to-digital converter; and a digital processing circuit 7 including memory as a hardware, for performing all the digital processing. It further includes: a memory card interface 8; a memory card 9; an LCD image display system 10; a system controller 11 including microcomputer as the main component thereof; an operation switch system 12; an operation display system 13; a strobe 14; a lens driver 15; an exposure control driver 16; and an EEPROM 17.

Fig.3 shows an example of the randomized color filter array of the CCD image pickup device 4 to be used as the color image pickup device in the embodiment shown in Fig.2. While the number of pixels of the CCD image pickup device 4 can be determined at will, it is here supposed as of the order of 1,000,000 pixels. Fig.2 shows only the filter array corresponding to 8×8=64 pixels at a center portion. The following description will specifically explain the procedure for obtaining such randomized array. The illustrations in the figures are only to facilitate understanding and it is thought that an illustration of such region is sufficient for the understanding. Further, since the substance of the present invention consists in a randomized arrangement, it is meaningless and impossible to show an example of pattern of the entire region. The kind of filter in the present embodiment uses the so-called RGB,

three primary colors, and the coding thereof is RGB random filter coding.

A description will now be given of an example of procedure for obtaining such random filter coding. Since this coding is a random coding, it is naturally possible to use a die by assigning two sides thereof to each of RGB in order to decide a color filter for each pixel. To reduce complexity thereof, however, a spread sheet software product or the like is used to prepare a table form corresponding to the entire pixel array. Here, "0 → R, 1 → G, 2 → B" for example can be applied to the values obtained by allocating $MOD(RND/3)$ to the respective cells of the array, where RND is a random number function of suitable figures and $MOD(n/d)$ is a remainder function obtained by dividing n by d.

Statistically, thus obtained array usually does not possess a conspicuous bias. It is possible, however, though unlikely in probability, that one obtained by a single trial contains an extremely large variance in quantity of pixels by colors or a concentration of a specific color in a relatively large area. Also, though very unlikely, the possibility of resulting in a pattern having a cyclicity such as a conventional Bayer array cannot be denied. For this reason, it is preferable to obtain a plurality of sample arrays by performing several times of trails by the above described methods. One evaluated as favorable is then

adopted by conducting imaging tests by actual picture
taking (in practice suitably using a simulation).
Characteristic bias of the above described types can be
statistically removed without difficulty by trials of equal
to or less than three to four times.

In the color image pickup apparatus (digital camera)
using the CCD image pickup device 4 having such random
color filter array, signals are read out and processed in a
similar manner as the conventional cameras. The picked up
image is recorded on the memory card 9 or displayed on the
LCD image display system 10. The operation different from
that of the convention is color separation processing
(color signal generation processing). Such color
separation processing is performed by the digital
processing circuit 7 under the control of the system
controller 11.

The color separation processing is fundamentally a
signal supplementation using neighboring pixel information
or the like for a pixel without a corresponding color signal
(such as R filter pixel in the process of B signal
generation) and is not at all different from the convention
in this respect. In the conventional color separation
processing, however, methodical sampling based on a
sequence is executed corresponding to a regular color
coding of the CCD image pickup device. Simple

supplementations using a hold circuit or the like, and additions, subtractions, etc., among the pixels as required are then performed. The actual processing varies among analog processing, digital processing, hybrid processing, etc. By contrast, the random color coding to be used in the present invention has no regularity and hence cannot be subject to such processing. For this reason, the color separation processing is performed by looking up the filter coding data concerning the pixels of CCD image pickup device to be used, i.e., a filter table of all the pixels corresponding to Fig.3. Such filter coding data is stored in the EEPROM 17 so that it can correspond to a case where the color coding of CCD image pickup device to be used is different.

The actual color separation processing (generation of each color signal) of the present embodiment is performed as follows. In particular, "the filter coding data is first looked up concerning the referred, subject pixel; signal level of the pixel is outputted without being changed as a signal for the color signal of the color of filter of the pixel itself; and, for the signal of other colors, the neighboring pixels are searched based on the filter coding data for the pixel of the nearest, corresponding color filter and the signal level of the applicable pixel is outputted without change as a signal of

that color."

When the filter of the referred, subject pixel is of R, the color separation processing is for example as follows.

R signal: since the result of looking up the filter coding data is R, the signal level of the pixel is outputted as R signal without being changed.

G signal: since the result of looking up is R and not G, the neighboring pixels are searched for the nearest G pixel based on the filter coding data and the signal level of the applicable pixel is outputted as G signal.

B signal: since the result of looking up is not B likewise, the neighboring pixels are searched for the nearest B pixel based on the filter coding data and the signal level of the applicable pixel is outputted as B signal.

In the example of the above color separation processing, suppose for example that the pixels of (R, G, B, B) filters are disposed respectively at (above, below, left to, right to) the referred R filter pixel. While there are two "nearest B" pixels on the left and right sides, it is possible in such case either to use the signal level of only one of the two or to use the average of the signal levels of the two.

The color signals obtained as a result of color

2 0

separation processing such as the above are processed as concurrent, RGB three primary-color signals with respect to all the pixels in a circuit at a later stage similarly as the conventional RGB three primary-color signals. Finally, they are recorded on the memory card 9 or displayed on the LCD image display system 10. It should be noted that such processing in the circuit at a later stage is per se known and for example includes: color balance processing; conversion to luminance - color difference signal by matrix operation or inversion processing thereof; false color elimination or reduction by band limitation or the like; various non-linear processing typically represented by γ - conversion; various information compression processing; etc.

The occurrence of false color in such processing will now be considered. For such objects as black-and-white knife edge or an isolated white point (line) or the like, false colors similar to that of the conventional color coding occur naturally due to the effect of the plane color coding. These however, are false color points or color lines all occurring in isolation. Since their main energy is distributed in a high-frequency region, they can be eliminated or sufficiently reduced by such techniques as a known electrical filtering. Further, in imaging of stripe-like repetitive pattern which has been the most serious

21

problem in the conventional system, at least a false color
(color moire) in lower region by folding to low frequency
(an aliased low frequency) does not occur, since the coding
is randomized. In the present embodiment, therefore, the
occurrence of false color is limited to those in isolation
which can be eliminated or be reduced as described above.
Hence it is possible to obtain a high quality image almost
free from false colors which cause a visual problem,
despite the fact that the present embodiment does not use an
optical low-pass filter which has been necessary in the
conventional digital camera of this type.

While a description has been given with respect to
the first embodiment, various modifications are possible of
the above described embodiment. First, in the above
described embodiment, the filter coding data is stored in
the EEPROM 17 so that it can correspond to the case where
the color filter coding of CCD image pickup device to be
used is different. Since CCD image pickup devices in many
cases require pixel defect data that differs from one unit
to another due to variance in mass production, the use of
EEPROM can be advantageous when used also as a memory for
such purpose. On the other hand, since the image pickup
devices applicable to one image pickup apparatus body are
usually of one type and identical to each other except their
variance due to mass production. Since change in the color

filter coding is not specifically required, the same data

can be used as the filter coding data for all. By noticing

this point, the above described EEPROM can be replaced by a

mask ROM. If replaced by mask ROM, construction costs can

be lowered. Furthermore, in either case, it can naturally

be used also as a program storage memory of the

microcomputer of the system controller 11.

As also described at the beginning, the present

invention intends to solve an essential problem inherent to

image pickup device irrespective of its electrical

construction (whether it comprises an image pickup tube or

solid-state image, whether it is a CCD or other type, etc.)

and/or the kind of color coding (whether it uses primary

colors or complementary colors, whether it uses three

colors or four colors, etc.). Hence it is applicable not

only to the above embodiment but also to any one of the

color image pickup devices including the above described

types and to the image pickup apparatus using the same. For

example, it can be used in a multi-sensor camera. It is

applicable without modification such as to R/B sensor of

G,R/B-type two-sensor color camera.

Further, "the procedure for obtaining random filter

coding" has been shown merely as an example in the above

embodiment and the random filter coding per se can be

obtained by other suitable methods. In particular, an

array is said to be a random color coding array of the present embodiment, if the pertinent color filter coding array is different from known regular arrays and is without a conspicuous, regular (cyclic) arrangement when a predetermined region of at least several to several tens of pixels of the array of photoelectric conversion elements is considered, thereby reducing occurrence of low-frequency false color for an input of stripe-like repetitive pattern which is caused by a conventional regular array.

A second embodiment of the invention will now be described. Since the fundamental construction of color image pickup apparatus (digital camera) according to the second embodiment is identical to that of the digital camera of the first embodiment shown in Fig.2, it is incorporated herein by reference and an illustration thereof will be omitted.

The digital camera according to the second embodiment differs from the digital camera according to the first embodiment in that color filter having a randomized color coding array satisfying predetermined array restricting conditions is used as the color filter in the CCD color image pickup device 4.

In the first embodiment, one having a color coding array in the form of a simple random array is used as the color filter of the CCD image pickup device 4. As

described above, one evaluated as favorable by imaging tests

based on actual picture taking is adopted as such random

color coding array, after obtaining a plurality of samples

of array by performing several times of trials by using a

spread sheet software product, random number function,

remainder function, etc.

Such a trial method, in general, however, greatly

reduces design efficiency and is not preferable if dependent

on the trials alone from the start of designing, even

though it is necessarily used in finally selecting an

array. In another perspective, there should be some

necessary conditions also in evaluating the arrays obtained

by such trials, which are objective and must be met by the

array itself to obtain a favorable imaging quality. (It is

obvious that an extreme case where all the pixels are of

the same color is not acceptable.) It is remarkably

effective to specifically find out such conditions and to

use these as the restricting conditions (criterion).

In the present embodiment, such restricting

conditions are used in setting a random color coding array.

In particular, the color image pickup device of the present

embodiment uses the restricting conditions: "at least one

pixel for each of R, G, B must be included in any one of

arbitrarily selected 3×3 pixel regions." This prescribes a

limit of sparseness in density (minimum density condition)

of each specified color and hence secures a resolution of a predetermined value or greater for that color. Fig.4 shows a color filter of random color coding array satisfying such restricting conditions.

It should be noted that an array satisfying such restricting conditions can be obtained either such that a large number of completely randomized arrays as used in the first embodiment are provided by trials and they are verified by the above conditions or such that restricting conditions are previously imposed on the generation process in generating an array for example by such software product as spread sheet.

In a color image pickup apparatus (digital camera) using the CCD image pickup device 4 having a random color filter array satisfying such restricting conditions, signals are read out and processed in a similar manner as in the camera of the first embodiment. The picked up image is recorded in the memory card 9 or displayed on the LCD image display system 10. The operation different from the convention is color separation processing. Such processing is performed by the digital processing circuit 7 under the control of the system controller 11. Since there is no regularity in the random coding which is applicable to the present embodiment, the color separation processing is performed by looking up the filter coding data (filter

table of all the pixels corresponding to Fig.4) in respect
of each pixel of the CCD image pickup device to be used.
Such coding data is stored in EEPROM 17 so that it can
correspond to a case where the color coding of CCD image
pickup device to be used is different.

The actual color separation processing (generation
of each color signal) of the present embodiment is
performed in a similar manner as the first embodiment. In
particular, "the coding data is first looked up concerning
the referred, subject pixel; signal level of the pixel is
outputted without being changed as a signal for the color
signal of the color of filter of the pixel itself; and, for
the signal of other colors, the neighboring pixels are
searched based on the coding data for the pixel of the
nearest, corresponding color filter and the signal level of
the applicable pixel is outputted without change as a signal
of that color."

The color signals obtained as a result of color
separation processing such as the above are subjected to
various processing as concurrent, RGB three primary-color
signals with respect to all the pixels in a circuit at a
later stage similarly as the conventional RGB three primary-
color signals. Finally, they are recorded on the memory
card 9 or displayed on the LCD image display system 10.

The occurrence of false color in such process will

now be considered. In imaging of stripe-like repetitive

pattern which has been the most serious problem in the

conventional system, at least a false color (color moire)

in lower region by folding to low frequency (an aliased low

frequency) does not occur, since the coding is randomized.

 In the present embodiment, similarly as in the first

embodiment, the occurrence of false color is limited to

those in isolation which can be eliminated or be reduced.

Hence it is possible to obtain a high quality image almost

free from false colors which cause a visual problem, despite

the fact that the present embodiment does not use an

optical low-pass filter which has been necessary in the

conventional digital camera of this type.

       In addition, since all of the three colors of R, G,

B exist in an arbitrarily selected 3×3 pixel region in the

present embodiment, the maximum value of blur of pixels,

i.e., width of PSF (point spread function), is not greater

than 5×5 pixels. Even if a local degradation in resolution

occurs, it is possible to secure a color resolution of the

order of 1/2 comparing to R and B in "the case of using an

average value of neighboring pixels instead of one pixel in

the supplementation at the time of color separation with a

conventional Bayer array". Furthermore, this is a

comparison based solely on the effect of pure pixel

sampling. It is thus in effect possible to obtain a

resolution somewhat higher than this, since there is no optical low-pass filter which causes a deterioration in response.

Various modifications are possible also of the present embodiment. First, setting of the region of the above described restricting conditions can be changed at will. For example, if a pixel region of 2×2 pixels is set, the width of PSF is 3×3 pixels at the maximum whereby the lower limit of local deterioration in resolution can be improved to the level of R and B in the above described conventional Bayer array. In such case, since a narrower restriction reduces the degree of freedom in constructing an array, it is thought that the effect of randomization is relatively lowered. There is a trade-off. Conversely, therefore, a loosening of restriction by using a region of 4×4 pixels or more is also a consideration. Further, the shape of a region can also be arbitrarily determined. If a rectangular region is used, a difference can be made in the limit of local resolution deterioration between horizontal and vertical directions. If a cross is used, it is possible to relatively inhibit deterioration in resolution along oblique directions.

Further, the above embodiment has been shown as that in which the coding data is stored in EEPROM 17 so that it can correspond to a case where the coding of CCD image

pickup device to be used is different. In the present

embodiment, too, the EEPROM can be replaced by a mask ROM.

If replaced by mask ROM, construction costs can be lowered.

Furthermore, in either case, it can naturally be used also

as a program storage memory of the microcomputer of the

system controller 11.

A third embodiment of the invention will now be

described. Since the fundamental construction of color

image pickup apparatus (digital camera) according to the

third embodiment is also identical to that of the digital

camera of the first embodiment shown in Fig.2, it is

incorporated herein by reference and an illustration thereof

will be omitted.

The digital camera according to the third embodiment

differs from the digital camera according to the first

embodiment in that color filter having a randomized color

coding array satisfying predetermined color distributing

conditions is used as the color filter in the CCD color

image pickup device 4.

In the first embodiment, one having a color coding

array in the form of a simple random array is used as the

color filter of the CCD image pickup device 4. As

described above, one evaluated as favorable by imaging tests

based on actual picture taking is adopted as such random

color coding array, after obtaining a plurality of samples

of array by performing several times of trials by using a

spread sheet software product, random number function,

remainder function, etc.

Such a trial method, in general, however, greatly

reduces design efficiency and is not preferable. Further,

there should be some necessary conditions also in

evaluating the arrays obtained by such trials, which are

objective and must be met by the array itself to obtain a

favorable imaging quality. It is remarkably effective to

specifically find out such conditions and to use these as

the restricting conditions (criterion).

In the present embodiment, predetermined color

distributing conditions are used in setting the random

color coding array. In particular, the color image pickup

device of the present embodiment uses as a restricting

condition ①: "for the total effective pixel area, the pixel

number ratios R/G, G/B, B/R each are substantially "1"

(allowable range 0.89 - 1.12)". Although the ideal target

value is "1", the exact value "1" cannot be achieved due to

the essential (statistical) nature of a random array.

Verification is made by setting an allowable range of values

by which a substantially equivalent performance is

expected. This prescribes a relative ratio of occurrence

for each of the colors so as to secure a high average

resolution for the signals. (It can also be said that this

is set to the same ratio as the RGB ratio in the
conventional stripe array.) Here the criterion in setting
the allowable range is±1.0dB. (The criterion for allowable
range is the same throughout the following unless otherwise
specified.) Fig.5 shows a filter of random color coding
array satisfying such predetermined color distributing
conditions.

The restricting condition ① concerns the total
effective pixels and hence does not directly restrain (is
not a necessary condition of) the exemplary array in Fig.5
which shows a segment thereof. Actually, however, the 8×
8 pixels illustrated in Fig.5 satisfy the restricting
condition ①, since the pixel number of each color is: R=22;
G=22; and B=20. Accordingly, the exemplary array shown in
Fig.5 constitutes an embodiment of imaginary image pickup
device having a small number of pixels or the total
effective pixels of 64. At the same time, it typically
represents one sufficient condition in a sense that, if each
of all possible 8×8 regions in the total effective pixels
satisfies for example the condition as shown in Fig.5, the
restricting condition ① is satisfied as a whole in an
image pickup device having a large number of pixels as
actually used in this embodiment.

It should be noted that an array satisfying such
restricting conditions can be obtained either such that a

large number of completely randomized arrays as used in the above first embodiment are provided by trials and they are verified by the above conditions or such that restricting conditions are previously imposed on the generation process in generating an array for example by such software product as spread sheet.

A modification will be shown below as one directly corresponding to an example generated by such technique as of the latter, where the target value of pixel number ratio of RGB is determined to be 1:2:1. In particular, an additionally higher average resolution can be obtained in respect of luminance signals by setting the same ratio as the RGB ratio in the conventional Bayer array so that a greater number of pixels are distributed to G which has a greater contribution to luminance signals. At this time, a similar spread sheet software product as the above can be used. A formula MOD(RND/4) is allocated to each cell of the array and it suffices to apply for example "0→R, 1→G 2→G, 3→B" to the obtained values. A random array having the aimed ratio can be obtained if the random numbers are not specifically biased.

Since, however, a statistical bias can occur also in this case in a similar manner as the above, verification is finally made by a restricting condition ② : "for the total effective pixel area, the pixel number ratios R/G, B/G each

are substantially "0.5" (allowable range 0.45 - 0.56)", and
one satisfying this is adopted. An exemplary array
corresponding to this modification is shown in Fig.6 which
is similar in significance to Fig.5 of the third embodiment.

The pixel number of each color is R=15, G=33, and B=16 and
hence a condition corresponding to the restricting
condition ② is satisfied.

It should be pointed out here that such target value
can be set to any desired value by the random array of the
present embodiment, while the setting of pixel ratio in the
case of cyclic array such as the conventional Bayer array
can be set only to ratios obtained by distributing the
number of pixels in a unit array to the respective colors.
Actual examples of such ratio target value (R/G, B/G) for
example include: ③(0.7, 0.7); ④(0.43, 0.43); ⑤(0.15,
0.15); ⑥(0.51, 0.19). The setting of ③ is a value
between the above restricting conditions ① and ② and is
an example of setting to an intermediate ratio between the
conventional stripe and Bayer arrays. Color distribution
of ④ corresponds to the color bandwidths of the standard
NTSC television system (I=1.5MHz, Q=0.5MHz); and ⑤
corresponds to the color bandwidths of the narrow-band NTSC
television system (B-Y=0.5MHz, R-Y=0.5MHz). (The result of
subtracting the total of the respective color difference
signal bandwidths from the luminance signal bandwidth 4.3MHz

is distributed to G and the total of the color difference

signal bandwidths is divided equally to R and B.) Color

distribution of ⑥ corresponds to the contributing ratio of

RGB in generating luminance signal Y. It is in this manner

possible to set also the ratio of R and B at will.

In a color image pickup apparatus (digital camera)

using the CCD image pickup device 4 having a random color

filter array satisfying such predetermined color

distributing conditions, signals are read out and processed

in a similar manner as in the camera of the first or second

embodiment. The picked up image is recorded in the memory

card 9 or displayed on the LCD image display system 10.

The operation different from the convention is color

separation processing. Such processing is performed by the

digital processing circuit 7 under the control of the

system controller 11. Since there is no regularity in the

random coding which is applicable to the present embodiment,

the color separation processing is performed by looking up

the filter coding data (filter table of all the pixels

corresponding to Fig.5 or 6) in respect of each pixel of

the CCD image pickup device to be used. Such coding data is

stored in EEPROM 17 so that it can correspond to a case

where the color coding of CCD image pickup device to be

used is different.

The actual color separation processing (generation

of each color signal) of the present embodiment is performed in a similar manner as the first or second embodiment. In particular, "the coding data is first looked up concerning the referred, subject pixel; signal level of the pixel is outputted without being changed as a signal for the color signal of the color of filter of the pixel itself; and, for the signal of other colors, the neighboring pixels are searched based on the coding data for the pixel of the nearest, corresponding color filter and the signal level of the applicable pixel is outputted without change as a signal of that color."

The color signals obtained as a result of color separation processing such as the above are subjected to various processing as concurrent, RGB three primary-color signals with respect to all the pixels in a circuit at a later stage similarly as the conventional RGB three primary-color signals. Finally, they are recorded on the memory card 9 or displayed on the LCD image display system 10.

The occurrence of false color in such process will now be considered. In imaging of stripe-like repetitive pattern which has been the most serious problem in the conventional system, at least a false color (color moire) in lower region by folding to low frequency (an aliased low frequency) does not occur, since the coding is randomized. In the present embodiment, similarly as in the first or

second embodiment, the occurrence of false color is limited

to those in isolation which can be eliminated or be

reduced. Hence it is possible to obtain a high quality

image almost free from false colors which cause a visual

problem, despite the fact that the present embodiment does

not use an optical low-pass filter which has been necessary

in the conventional digital camera of this type.

In addition, the present embodiment satisfies the

above described color distributing conditions. In

particular, an image is obtained with favorable color

reproduction where the average resolutions of RGB are

substantially equal to each other if the restricting

condition ① in the above embodiment is satisfied; and an

image is obtained with an average luminance resolution as

high as that of Bayer array if the restricting condition ②

in the above modification of the embodiment is satisfied.

Furthermore, since, unlike the convention, no optical low-

pass filter is used, the lowering of response due to this

does not occur and the actually obtained resolution is

additionally higher.

In addition, various other modifications are

possible of the present embodiment. First, all of the

color distribution restricting conditions of the above

embodiment are to restrict only "the pixel number ratio of

the total effective pixel area" and hence to secure average

resolution of the imaging area as a whole. In such case, if distribution is biased, there remains the possibility of a local degradation in color resolution. Hence, a yet greater advantage can be obtained by introducing, in addition to the above restriction concerning the total effective pixel area, for example, a block restricting condition C(N,M) so that local resolutions can also be secured by imposing a restricting condition: "'pixel number ratio concerning optionally selected N×M pixel region (N,M: constants represented by integer) within the effective pixel region' is restricted to the same ratio conditions as in the above embodiment".

Here, since the number of pixels to be contained in such block is smaller if the values of N, M are relatively small, it is impossible in some cases to satisfy the pixel number setting of the allowable range such as the above as it is. Hence it is necessary to change the setting of the allowable range in accordance with the setting of the constants N, M. For example, since the pixel number in a block is 16 pixels in the case of C(4,4), only the case of 5.3 (allowable range 5.1 - 5.8) pixels for each of RGB is theoretically allowable in order to satisfy a target value corresponding to the above restricting condition ①. Naturally this cannot be satisfied. Hence the allowable condition of such local pixel number is loosened as compared

to those concerning the entire area. For example, "5 pixels or 6 pixels" is applied.

Further, the above embodiment has been shown as that in which the coding data is stored in EEPROM 17 so that it can correspond to a case where the coding of CCD image pickup device to be used is different. In the present embodiment, too, the EEPROM can be replaced by a mask ROM. If replaced by mask ROM, construction costs can be lowered. Furthermore, in either case, it can naturally be used also as a program storage memory of the microcomputer of the system controller 11.

A fourth embodiment of the invention will now be described. Since the fundamental construction of color image pickup apparatus (digital camera) according to the fourth embodiment is also identical to that of the digital camera of the first embodiment shown in Fig.2, it is incorporated herein by reference and an illustration thereof will be omitted.

In the digital camera according to the fourth embodiment, at the same time of making it possible to perform a high quality color imaging free from color moire even of an object having cyclic luminance change by using a color filter having random color coding array as the color filter of CCD image pickup device, pixel defect correction is performed based on pixel defect data at the time of

color signal generation processing based on the color coding array data by storing to EEPROM array data concerning the random color coding array of the color filter and the pixel defect data.

The color filter to be used in the CCD image pickup device will first be described. A totally randomized array as shown in the first embodiment may be used as the color filter having the random color coding array. As described above, in such a case, one evaluated as favorable by imaging tests based on actual picture taking is adopted after obtaining a plurality of samples of array by performing several times of trials by using a spread sheet software product, random number function, remainder function, etc.

Such a trial method, in general, however, greatly reduces design efficiency and is not preferable. Further, there should be some necessary conditions also in evaluating the arrays obtained by such trials, which are objective and must be met by the array itself to obtain a favorable imaging quality. It is remarkably effective to specifically find out such conditions and to use these as the restricting conditions (criterion).

In the present embodiment, therefore, one satisfying such predetermined color coding array conditions is preferably used as the color filter. In particular, the

CCD image pickup device in the present embodiment uses a color filter adopted under the restricting conditions that an arbitrarily selected pertinent pixel is in contact at one or more of its four sides with the two colors other than the filter color of the pertinent pixel (its own color) and is in contact with at one or more of its four sides or four corners the same color as the filter color of the pertinent pixel (its own color).

In particular, supposing that the filter of the pertinent pixel is R, the former condition of the color filter consist in the condition that at least one pixel each of G and B are contained in the four pixels with which it is in contact at its upper, lower, left and right sides. This condition secures that a supplementation based on nearest pixel information in the color separation processing to be described later is performed necessarily by using a contiguous pixel on upper, lower, left or right side thereof and hence to secure a high resolution equal to or above a certain value. Furthermore, according to the latter restricting condition, even if a pixel defect (supposedly isolated) occurs, since there is always the same color as the filter color of the pertinent pixel (own color) in the adjoining eight pixels in the up and down, left and right and oblique directions, deterioration of resolution is practically prevented by thus supplementing such pixel

defect.

Fig.7 shows a filter of random color coding array
satisfying such predetermined color coding array conditions.

In the exemplary array shown in Fig.7, while some of the
pixels in each one of the outermost rows and columns
apparently do not satisfy the above array restricting
conditions, these do satisfy the conditions by the existence
of pixels at further outside (not shown). Under the
circumstances, the photoelectric conversion surface of the
image pickup device is provided with a margin of one to
several rows (columns) for each of the four sides from the
effective image area to form the so-called "waste pixel
region" (region participating in image signal generation but
not included in the effective image area).

It should be noted that an array satisfying such
restricting conditions can be obtained either such that a
large number of completely randomized arrays as described
above are provided by trials and they are verified by the
above conditions or such that restricting conditions are
previously imposed on the generation process in generating
an array for example by such software product as spread
sheet.

In a color image pickup apparatus (digital camera)
using the CCD image pickup device 4 having a random color
filter array satisfying such predetermined color coding

4 2

array conditions, signals are read out and processed in a similar manner as in the camera of the first to third embodiments. The picked up image is recorded in the memory card 9 or displayed on the LCD image display system 10. The operation different from the convention is color separation processing. Such processing is performed by the digital processing circuit 7 under the control of the system controller 11. Since there is no regularity in the random coding which is applicable to the present embodiment, the color separation processing is performed by looking up the filter coding data (filter table of all the pixels corresponding to Fig.7) in respect of each pixel of the CCD image pickup device to be used. Such coding data is stored in EEPROM 17 so that it can correspond to a case where the color coding of CCD image pickup device to be used is different.

Further, pixel defect data as to which ones of the pixels are fault pixels incapable of normally outputting information is also stored in EEPROM 17. Based on such pixel defect data, the pixel defect correction processing is performed at the same time of color separation in the digital processing circuit.

The actual color separation processing (generation of each color signal) including pixel defect correction processing of the present embodiment is performed as

follows. In particular: "the pixel defect data is first looked up concerning the referred, subject pixel so as to determine whether it is a defect pixel or not; if not a fault pixel, the coding data is looked up and signal level of the pixel is outputted without being changed as a signal for the color signal of the filter color of the pixel itself; and, for the signal of other colors, the neighboring pixels are searched based on the filter coding data for the pixel of the nearest, corresponding color filter (excluding fault pixel) and the signal level of the applicable pixel is outputted without change as a signal of that color. If the subject pixel is a fault pixel, for all of the respective color signals, the neighboring pixels are searched based on the coding data for the pixel (excluding fault pixel) of the nearest, corresponding color filter, and the signal level of the applicable pixel is outputted as a signal of that color."

When the filter of the referred, subject pixel is of R, the color separation processing is for example as follows.

(1) If the subject R pixel to be referred to is not a fault pixel, outputs are provided as follows.

R signal: since the result of looking up the coding data is R, the signal level of the pixel is outputted as R signal without being changed.

G signal: since the result of looking up is not G, the neighboring pixels are searched for the nearest G pixel (excluding fault pixel) based on the coding data and the signal level of the applicable pixel is outputted as G signal.

B signal: since the result of looking up is not B, the neighboring pixels are searched for the nearest B pixel (excluding fault pixel) based on the coding data and the signal level of the applicable pixel is outputted as B signal.

(2) If the subject R pixel to be referred to is a fault pixel, outputs are provided as follows.

R signal: the neighboring pixels are searched based on the coding data for the nearest R pixel (excluding fault pixel) and the signal level of the applicable pixel is outputted as R signal.

G signal: the neighboring pixels are searched based on the coding data for the nearest G pixel (excluding fault pixel) and the signal level of the applicable pixel is outputted as G signal.

B signal: the neighboring pixels are searched based on the coding data for the nearest B pixel (excluding fault pixel) and the signal level of the applicable pixel is outputted as B signal.

In the example of the above color separation

processing, suppose for example that the pixels of (R, G, B, B) filters are disposed at (above, below, left to, right to) the referred R filter pixel. While there are two " nearest B" pixels on the left and right sides, it is possible in such case either to use only one of the two or to use the average of the two.

The color signals obtained as a result of color separation processing such as the above are subjected to various processing as concurrent, RGB three primary-color signals with respect to all the pixels in a circuit at a later stage similarly as the conventional RGB three primary-color signals. Finally, they are recorded on the memory card 9 or displayed on the LCD image display system 10.

The occurrence of false color in such process will now be considered. In imaging of stripe-like repetitive pattern which has been the most serious problem in the conventional system, at least a false color (color moire) in lower region by folding to low frequency (an aliased low frequency) does not occur, since the coding is randomized. In the present embodiment, similarly as in the first to third embodiments, the occurrence of false color is limited to those in isolation which can be eliminated or be reduced. Hence it is possible to obtain a high quality image almost free from false colors which cause a visual problem, despite the fact that the present embodiment does

not use an optical low-pass filter which has been necessary in the conventional digital camera of this type.

In addition, since, in the present embodiment, supplementation based on nearest pixel information in the color separation processing is always performed by adjoining pixels at above, below, left or right, the maximum value of blur of pixels, i.e., the maximum value of width of PSF (point spread function) is not greater than 3 pixels. It is possible to secure a color resolution of about the same for G and of the order of 2 times for R, B comparing to "the case of a conventional Bayer array using an average value of neighboring pixels instead of one pixel in the supplementation at the time of color separation". Further, a supplementation in the case of an isolated pixel defect is considered. While a maximum of 5 pixels must be allowed as the width of PSF in the case of Bayer array, the maximum width of PSF in the present embodiment is unchanged from three pixels at least with respect to horizontal and vertical directions, since an isolated pixel defect can be supplemented by the referred pixel's color (own color) existing at one of the eight pixels which are adjoining thereto in the four directions of up and down, left and right and diagonals. (If supplementation of other colors in supplementing the referred pixel's color is considered, the maximum width is 7 pixels and 5 pixels, respectively.)

Furthermore, this is a comparison based solely on the effect of pure pixel sampling. Since, in addition, this does not use any optical low-pass filter which causes a deterioration in response, the resolution can be extended into a frequency range where it has conventionally been impossible to resolve an image.

Various modifications are possible also of the present embodiment. First, the above embodiment has been shown as that in which the coding data and pixel defect data are stored in EEPROM 17 so that it can correspond to a case where the coding of CCD image pickup device to be used is different. Although this is a natural construction in view of using the memory for a double purpose, it is also possible that the EEPROMs serving as the storage means for storing the two types of data can be of separated bodies from each other. If only the coding data is considered at this time, since the image pickup devices applicable to one image pickup apparatus body are usually of one type and identical to each other (except their variance due to mass production). Since change in the color coding is not specifically required, the same data can be used as the coding data for all. By noticing this point, the above described EEPROM can be replaced for example by a mask ROM similarly as in the above described embodiments. If replaced by mask ROM, construction costs can be lowered.

Furthermore, in either case, the memory serving as the means for storing these two types of data can naturally be used also as a program storage memory of the microcomputer of the system controller 11.

WHAT IS CLAIMED IS:

1.   A color image pickup device comprising:

        a pixel group placed in an array of a plurality of

pixels of photoelectric conversion elements; and

        a color coding array corresponding to the pixel

group, arranged in a randomized array.

2.   The color image pickup device according to claim 1,

wherein said color coding array comprises a color filter.

3.   A color image pickup apparatus comprising:

        a color image pickup device having a pixel group

placed in an array of a plurality of pixels of

photoelectric conversion elements and a color coding array

corresponding to the pixel group, arranged in a randomized

array; and

        color separation means for performing color

separation processing of output signals of the color image

pickup device in accordance with the random color coding

array of the color image pickup device.

4.   The color image pickup apparatus according to claim

3, wherein said color coding array comprises a color filter.

5. The color image pickup apparatus according to claim 3 further comprising storage means for storing array data concerning the random color coding array of said color image pickup device, for performing color separation processing at said color separation means.

6. The color image pickup apparatus according to claim 5, wherein said storage means comprises mask ROM.

7. The color image pickup apparatus according to claim 5, wherein said storage means comprises EEPROM.

8. A color image pickup device comprising:
a pixel group placed in an array of a plurality of pixels of photoelectric conversion elements; and
a color coding array corresponding to the pixel group, arrayed in a randomized array satisfying predetermined array restricting conditions.

9. The color image pickup device according to claim 8, wherein said color coding array comprises a color filter.

10. The color image pickup device according to claim 8, wherein said array restricting conditions are minimum

density conditions concerning colors.

11.   A color image pickup apparatus comprising:

a color image pickup device having a pixel group placed in an array of a plurality of pixels of photoelectric conversion elements and a color coding array corresponding to the pixel group, arrayed in a randomized array satisfying predetermined array restricting conditions; and

color separation means for performing color separation processing of output signals of the color image pickup device in accordance with the random color coding array of the color image pickup device.

12.   The color image pickup apparatus according to claim 11, wherein said color coding array comprises a color filter.

13.   A color image pickup apparatus comprising:

a color image pickup device having a pixel group placed in an array of a plurality of pixels of photoelectric conversion elements and a color coding array corresponding to the pixel group, arrayed in a randomized array satisfying minimum density conditions concerning colors; and

color separation means for performing color separation processing of output signals of the color image pickup device in accordance with the random color coding array of the color image pickup device.

14.   The color image pickup apparatus according to claim 13, wherein said color coding array comprises a color filter.

15.   The color image pickup apparatus according to claim 11 further comprising storage means for storing array data concerning the random color coding array of said color image pickup device, for performing color separation processing at said color separation means.

16.   The color image pickup apparatus according to claim 13 further comprising storage means for storing array data concerning the random color coding array of said color image pickup device, for performing color separation processing at said color separation means.

17.   The color image pickup apparatus according to claim 15, wherein said storage means comprises mask ROM.

18.   The color image pickup apparatus according to claim

16, wherein said storage means comprises mask ROM.

19.   The color image pickup apparatus according to claim
15, wherein said storage means comprises EEPROM.

20.   The color image pickup apparatus according to claim
16, wherein said storage means comprises EEPROM.

21.   A color image pickup device comprising:
        a pixel group placed in an array of a plurality of
pixels of photoelectric conversion elements; and
        a color coding array corresponding to the pixel
group, arrayed in a randomized array satisfying
predetermined color distributing conditions.

22.   The color image pickup device according to claim 21,
wherein said color coding array comprises a color filter.

23.   A color image pickup apparatus comprising:
        a color image pickup device having a pixel group
placed in an array of a plurality of pixels of
photoelectric conversion elements and a color coding array
corresponding to the pixel group, arrayed in a randomized
array satisfying predetermined color distributing
conditions; and

color separation means for performing color
separation processing of output signals of the color image
pickup device in accordance with the random color coding
array of the color image pickup device.

24.   The color image pickup apparatus according to claim
23, wherein said color coding array comprises a color
filter.

25.   The color image pickup apparatus according to claim
23 further comprising storage means for storing array data
concerning the random color coding array of said color
image pickup device, for performing color separation
processing at said color separation means.

26.   The color image pickup apparatus according to claim
25, wherein said storage means comprises mask ROM.

27.   The color image pickup apparatus according to claim
25, wherein said storage means comprises EEPROM.

28.   A color image pickup apparatus comprising:
         a color image pickup device having a pixel group
placed in an array of a plurality of pixels of
photoelectric conversion elements and a color coding array

corresponding to the pixel group, arranged in a randomized array;

storage means for storing array data concerning the color coding array and pixel defect data of the color image pickup device; and

color separation means for generating color signals in accordance with the color coding array data stored in the storage means,

wherein said color separation means performing a predetermined pixel defect correction in the color signal generating process based on the pixel defect data stored in said storage means.

29. The color image pickup apparatus according to claim 28, wherein said color coding array comprises a color filter.

30. The color image pickup apparatus according to claim 28, wherein the predetermined pixel defect correction processing by said color separation means comprises processing where an output signal of a fault pixel is supplemented by using an output signal of the pixel nearest to the fault pixel among the pixels of the same color as the color of signal to be supplemented for the fault pixel.

31.   The color image pickup apparatus according to claim 28, wherein said storage means comprises EEPROM.

32.   The color image pickup apparatus according to claim 30, wherein said storage means comprises EEPROM.

Abstract of the Disclosure

A color image pickup device including: a pixel group placed in an array of a plurality of pixels of photoelectric conversion elements; and a color coding array corresponding to the pixel group, said color coding array arranged in a randomized array, or arranged in a randomized array satisfying predetermined array restricting conditions, or arranged in a randomized array satisfying predetermined color distributing conditions. Thereby an object image can be picked up in accordance with a randomized color coding array having no regularity, making it possible without using an optical low-pass filter to achieve a color image pickup device and color image pickup apparatus using the color image pickup device capable of keeping color moire from occurring even of an object having a cyclic luminance change.

FIG. 1A   PRIOR ART

G	B
R	G

FIG. 1B   PRIOR ART

G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G
G	B	G	B	G	B	G	B
R	G	R	G	R	G	R	G

FIG. 2

1 : LENS SYSTEM

2 — LENS DRIVE MECH

15 — LENS DRIVER

14 — STROBE

3 — EXPOSURE CONTROL MECHANISM

16 — EXPOSURE CONTROL DRIVER

4 — CCD

5 — CCD DRIVER

6 — PRE-PROCESSING CIRCUIT

7 — DIGITAL PROCESSING CIRCUIT

10 — LCD

9 — MEMORY CARD

8 : MEMORY CARD INTERFACE

11 — SYSTEM CONTROLLER

17 — EEPROM

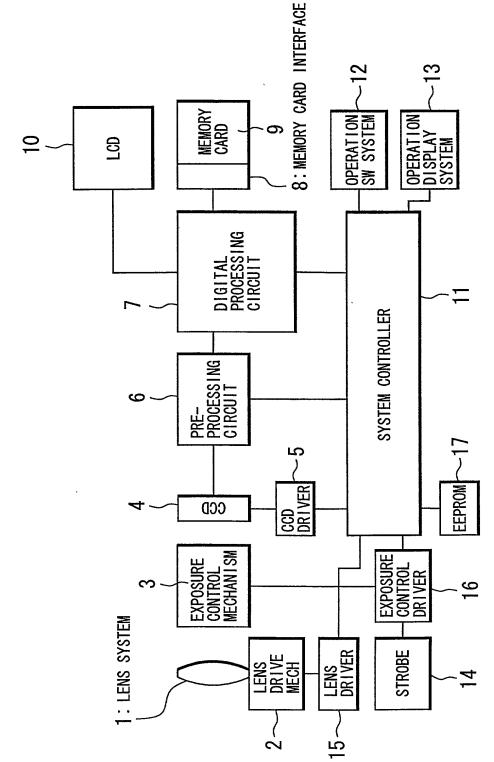12 — OPERATION SW SYSTEM

13 — OPERATION DISPLAY SYSTEM

FIG. 3

R	B	G	R	R	B	G	B
G	G	R	B	G	R	B	R
B	G	B	G	G	B	B	G
R	B	B	G	R	R	G	B
G	G	R	R	B	R	G	R
R	B	G	G	G	R	B	B
R	B	G	B	R	B	B	G
G	B	R	B	G	G	R	B

FIG. 4

G	R	R	G	R	B	G	R
B	B	B	G	B	G	G	B
R	G	G	R	B	B	R	G
B	B	G	R	G	G	B	R
G	R	G	B	R	G	G	R
G	B	R	R	R	B	R	B
R	B	B	G	G	B	B	G
B	G	B	R	B	G	R	B

FIG. 5

G	R	B	B	B	G	R	R
G	R	R	G	B	G	R	B
B	R	G	R	B	G	G	G
B	G	R	B	R	R	R	G
B	R	B	G	B	B	G	R
B	R	B	R	G	B	R	B
G	G	B.	G	R	B	R	G
G	G	G	R	G	R	R	B

FIG. 6

G	R	B	B	G	G	R	R
G	R	G	G	B	G	R	B
B	R	G	R	B	G	G	G
B	G	G	B	G	G	R	G
B	G	G	G	B	G	G	R
G	G	B	R	G	B	R	B
G	G	B	G	R	B	R	G
G	G	G	G	G	R	R	B

FIG. 7

R	B	G	R	R	B	G	B
G	G	R	B	B	R	R	R
B	G	R	G	G	G	B	G
R	B	B	G	R	R	G	B
G	G	R	R	B	B	G	R
R	B	G	G	G	R	B	B
R	B	G	B	R	B	B	G
G	B	R	B	G	G	R	B

Declaration and Power of Attorney for U.S. Patent Application
特許出願宣言書及び委任状
Japanese Language Declaration
日本語宣言書

下記の氏名の発明者として、私は以下の通り宣言します。

As a below named inventor, I hereby declare that:

私の住所、私書箱、国籍は下記の私の氏名の後に記載された通りです。

My residence, post office address and citizenship are as stated next to my name.

下記の名称の発明に関して請求範囲に記載され、特許出願している発明内容について、私が最初かつ唯一の発明者（下記の氏名が一つの場合）もしくは最初かつ共同発明者であると（下記の名称が複数の場合）信じています。

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor(if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled.

_____

_____

Color image pickup device and

color image pickup apparatus

上記発明の明細書（下記の欄で×印がついいないいい場合は、本書に添付）は、

the specification of which is attached hereto unless the following box is checked:

☐ ____月____日に提出され、米国出願または特許協定条約国際出願番号を_____ とし、（該当する場合）_____ に訂正されました。

☐ was filed on _____ as United States Application Number or PCT international Application Number _____ and was amended on _____ (if applicable).

私は、特許請求範囲を含む上記訂正後の明細書を検討し、内容を理解していることをここに表明します。

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

私は、連邦規則法典第３７編第１条５６項に定義されるとおり、特許資格の有無について重要な情報を開示する義務があることを認めます。

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

Japanese Language Declaration
（日本語宣言書）

私は、米国法典第３５編１１９条(a)-(d)項又は３６５条
(b)項に基づき下記の、米国以外の少なくとも一カ国を指定
している特許協力条約３６５(a)項に基づく国際出願、又は
外国での特許出願もしくは発明者証の出願についての外国
優先権をここに主張するとともに、優先権を主張している
、本出願の前に出願された特許または発明者証の外国出願を
以下に、枠内をマークすることで、示しています。

I hereby claim foreign priority under Title 35, United States Code, Section 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT international application having a filling date before that of the application on which priority is claimed.

Prior Foreign Application(s)
外国での先行出願

Priority Not Claimed
優先権主張なし

(Number) （番号）	(Country) （国名）	(Day/Month/Year Filed) （出願年月日）	
11-107371	Japan	15 April, 1999	☐
11-107372	Japan	15 April, 1999	☐
11-107440	Japan	15 April, 1999	☐
11-125494	Japan	6 May, 1999	☐

私は、第３５編米国法典１１９条(e)項に基づいて下記の
米国特許出願規定に記載された権利をここに主張いたしま
す。

I hereby claim the benefit under Title 35, United States Code, Section 119(e)of any United States provisional application(s) listed below.

(Application No.) （出願番号）	(Filing Date) （出願日）	(Application No.) （出願番号）	(Filing Date) （出願日）

私は、下記の米国法典第３５編１２０条に基づいて下記の
米国特許出願に記載された権利、又は米国を指定している特
許協力条約３６５条(c)に基づく権利をここに主張します。
また、本出願の各請求範囲の内容が米国法典第３５編１１２
条第１項又は特許協力条約で規定された方法で先行する米国
特許出願に開示されていない限り、その先行米国出願書提出
日以降で本出願書の日本国内または特許協力条約国際提出日
までの期間中に入手された、連邦規則法典第３７編１条５６
項で定義された特許資格の有無に関する重要な情報について
開示義務があることを認識しています。

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s), or 365(c) of any PCT international application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of Title 35, United States Code Section 112. I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56 which became available between the filling date of the prior application and the national or PCT international filing date of application.

(Application No.) （出願番号）	(Filing Date) （出願日）	(Status: Patented, Pending, Abandoned) （現況：特許許可済、係属中、放棄済）
(Application No.) （出願番号）	(Filing Date) （出願日）	(Status: Patented, Pending, Abandoned) （現況：特許許可済、係属中、放棄済）

私は、私自身の知識に基づいて本宣言書中で私が行う表明
が真実であり、かつ私の入手した情報と私の信じるところに
基づく表明が全て真実であると信じていること、さらに故意
になされた虚偽の表明及びそれと同等の行為は米国法典第１
８編１００１条に基づき、罰金または拘禁、もしくはその
両方により処罰されること、そしてそのような故意による虚
偽の声明を行えば、出願した、又は既に許可された特許の有
効性が失われることを認識し、よってここに上記のごとく宣
誓を致します。

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Japanese Language Declaration
（日本語宣言書）

委任状： 私は下記の発明者として、本出願に関する一切の
手続きを米特許商標局に対して遂行する弁護士または代理人
として、下記の者を指名いたします。（弁護士、または代理
人の氏名及び登録番号を明記のこと）

POWER OF ATTORNEY: As a named inventor, I hereby appoint
the following attorney(s) and/or agent(s) to prosecute this
application and transact all business in the Patent and Trademark
Office connected therewith (list name and registration number)
See list of attorneys and/or agents on page 5.

書類送付先

Send Correspondence to:
ARMSTRONG, WESTERMAN, HATTORI,
McLELAND & NAUGTON
1725 K Street, N.W., Suite 1000
Washington, D.C. 20006

直通電話連絡先：（名前及び電話番号）

Direct Telephone Calls to:(name and telephone number)

Telephone: (202)659-2930   Fax: (202)887-0357

唯一または第一発明者名		Full name of sole of first inventor Hideaki Yoshida	
発明者の署名	日付	Inventor's signature *Hideaki Yoshida*	Date *Mar. 30, 2000*
住所		Residence Hachioji-shi, Tokyo, Japan	
国籍		Citizenship Japanese	
私書箱		Post Office Address	

c/o Intellectual Property & Legal Department, OLYMPUS OPTICAL
CO., LTD., 2-3 Kuboyama-cho, Hachioji-shi, Tokyo, Japan

第二共同発明者		Full name of second joint inventor,if any Hatsuo Shimizu	
第二共同発明者の署名	日付	Second inventor's signature *Hatsuo Shimizu*	Date *Mar. 30, 2000*
住所		Residence Hachioji-shi, Tokyo, Japan	
国籍		Citizenship Japanese	
私書箱		Post Office Address	

c/o Intellectual Property & Legal Department, OLYMPUS OPTICAL
CO., LTD., 2-3 Kuboyama-cho, Hachioji-shi, Tokyo, Japan

（第三以降の共同発明者についても同様に記載し、署名をす
ること）

(Supply similar information and signature for third and subsequent
joint inventors.)

第三共同発明者		Full name of third joint inventor, if any	
第三発明者の署名	日付	Third inventor's signature	Date
住所		Residence	
国籍		Citizenship	
私書箱		Post Office Address	
第四共同発明者		Full name of fourth joint inventor, if any	
第四発明者の署名	日付	Fourth inventor's signature	Date
住所		Residence	
国籍		Citizenship	
私書箱		Post Office Address	
第五共同発明者		Full name of fifth joint inventor, if any	
第五発明者の署名	日付	Fifth inventor's signature	Date
住所		Residence	
国籍		Citizenship	
私書箱		Post Office Address	
第六共同発明者		Full name of sixth joint inventor, if any	
第六発明者の署名	日付	Sixth inventor's signature	Date
住所		Residence	
国籍		Citizenship	
私書箱		Post Office Address	

List of attorneys and/or agents

James E. Armstrong, III , Reg. No. 18,366; William F. Westerman, Reg. No. 29,988; Ken-Ichi Hattori, Reg. No. 32,861; Le-Nhung McLeland, Reg. No. 31,541; Ronald F. Naughton, Reg. No. 24,616;   John R. Pegan, Reg. No. 18,069; William G. Kratz, Jr., Reg. No. 22,631; James P. Welch, Reg. No. 17,379; Mel R. Quintos, Reg. No. 31,898; Donald W. Hanson, Reg. No. 27,133; Stephen G. Adrian, Reg. No. 32,878; William L. Brooks, Reg. No. 34,129; John F. Carney, Reg. No. 20,276; Edward F. Welsh, Reg. No. 22,455; Patrick D. Muir, Reg. No. 37,403; Gay A. Spahn, Reg. No. 34,978; John P. Kong, Reg. No. 40,054; Luke A. Kilyk, Reg. No. 33,251. Jones F. Armstrong, IV , Reg. No. P-42,266; and Leonard D. Bowersox, Reg. No. 33,226.